

Focus on Two Award-Winning Technologies

Versatile X-Ray Microprobe Analyzes Bacteria, Microchips, and More...



Large-Area X-Ray Detector Revolutionizes Structural Biology

Challenge

Conventional x-ray technology has profoundly affected our lives. However, the spatial resolution of conventional x-ray techniques is generally limited to 0.1–1.0 mm. A wide range of potential new applications for x-ray microscopy promises spatial resolution surpassing that of optical microscopes (Figure 1).

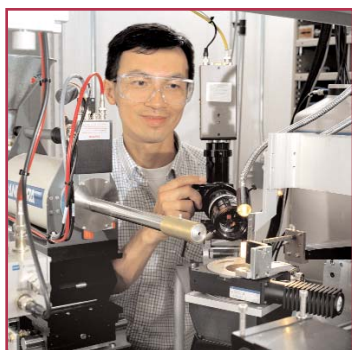


Figure 1. An x-ray microprobe developed by Argonne makes possible noninvasive microcharacterization of specimens as diverse as semiconductor materials and bacteria.

Argonne's Solution

Argonne researchers developed a scanning hard x-ray microprobe with < 0.0002 mm spatial resolution that uses the extremely bright x-rays generated by the Advanced Photon Source. A unique optical component, a “phase zone plate,” was created to help focus the x-ray beam. The microprobe beam has enough penetrating power to study specimens in vacuum, ambient pressure, or even in an aqueous environment. This versatile, noninvasive tool can be used to study a wide variety of samples and configurations, including thick and optically opaque samples, *in-situ* processes such as defect migration, and *in-vivo* hydrated biological cells and bacteria.

How Does the Technology Work?

Argonne's x-ray microprobe functions much like a scanning electron microscope (SEM), using a tightly focused x-ray beam instead of an electron beam (Figure 2). The microprobe can operate in five modes: (1) transmission, which measures absorption by the sample; (2) diffraction, where diffracted x-rays provide structural data 100 times more accurate than electron diffraction; (3) fluorescence, which reveals elemental distributions with 1,000 times more sensitivity than an electron probe;

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Challenge

High-energy x-ray beamlines at Argonne's Advanced Photon Source — which can help researchers determine the precise three-dimensional structures of proteins and macromolecules — are helping to revolutionize structural biology and opening up new horizons in cellular and metabolic processes, genetics, and pharmaceutical drug development. However, the usefulness of x-ray beamlines has been limited by the inability to efficiently and accurately capture the torrent of high-speed, high-precision information produced.

Argonne's Solution

Argonne scientists created the world's first large-area, charge-coupled device (CCD) x-ray detector (Figure 3). The detector captures x-ray diffraction pattern data with unprecedented speed and sensitivity, reducing the time it takes to solve complex molecular structures from days or hours to minutes.

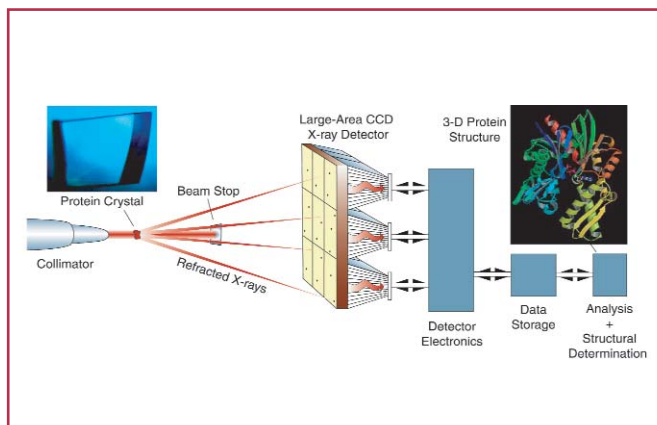


Figure 3. Argonne's large-area CCD x-ray detector

A group of Argonne scientists — leading experts in advanced protein crystallography research — called upon the expertise of the electronics and computational systems experts at Argonne in a multidisciplinary effort to develop the required x-ray detector technology.

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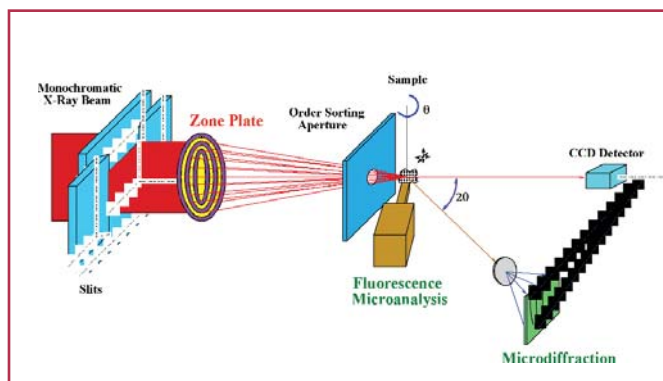


Figure 2. Diagram showing how the scanning x-ray microprobe works

(4) spectroscopy, which yields data on chemical speciation or local atomic arrangement; and (5) tomography, which allows reconstruction of the internal three-dimensional structure.

Impact

With a detection limit of 10–100 parts per billion, a better than 0.01% accuracy in structural analysis, and spatial resolution far exceeding that of optical microscopes, the Argonne microprobe has redefined the field of x-ray microscopy. The technology enables the microcharacterization of specimens as diverse as microelectronic devices, nuclear reactor materials, fine airborne particles, and bacteria — all at submicrometer resolution. No specimen preparation is required, even with samples that are hundreds of microns thick.

The Argonne scanning hard x-ray microprobe was named one of the top 100 technological innovations in 2000 by *R&D Magazine* in its R&D 100 Awards.

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Contact

Barry Lai
Experimental Facilities Division
Phone: 630/252-6405
Fax: 630/252-9303
E-mail: blai@aps.anl.gov



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How Does the Technology Work?

Argonne researchers faced a significant challenge: to increase the active detection area of a CCD chip, which typically is only a few inches square. They did it by connecting a fiber-optic taper (70 x 70 mm²) to each of nine CCD chips in a 3 x 3 array to achieve a full 210 x 210 mm² detection surface.

Achievements

Compared to conventional x-ray detectors, Argonne's CCD x-ray detector offers a very large active detection area, up to 100 times faster readout, and better resolution. It has already helped solve many molecular structures, including the human aldose reductase enzyme, which may help researchers find a treatment for diabetes. Argonne's detector has also resolved details on large molecules.

The Argonne CCD x-ray detector was named one of the top 100 technological innovations in 2000 by *R&D Magazine* in its R&D 100 Awards.

Impact

Today, Argonne's large-area CCD x-ray detector is playing a critical role in helping researchers understand biological processes and develop new pharmaceutical drugs based on protein crystallographic research (most pharmaceutical drug targets are proteins). The device has helped spur such new developments as vancomycin, a powerful new antibiotic used against the most aggressive bacterial infections.

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Contact

Istvan (Steve) Naday
Electronics and Computing Technologies Division
Phone: 630/252-6940
Fax: 630/252-4021
E-mail: snaday@anl.gov

